ES-2 Biofidelity and Injury Assessment Capability

May 2001

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National Highway Traffic Safety Administration

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Transportation Research Center

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Presentation Overview

- ES-2 Research Program Time Line
- Flat top and the ES-2
- Biofidelity of the ES-2 and SID
- Injury Assessment Capability of the ES-2 and SID
- Back Plate Loads in the ES-2
- Conclusions
- Future Work

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Why ES-2?

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- **NHTSA is evaluating the ES-2 . . .**
  - **. . . to Improve safety for the US Driving Population, and**
  - **. . . for interim regulatory harmonization of a side impact dummy**

ES-2 Research Testing

Planned

3-5/00 | 7/00 | 8/00-4/01 | 5-7/01 | 8/01

High mass impactor tests to evaluate ES-2 proposed rib designs: coated piston, ball bearing, & needle bearing

Second ES-2 Available

- Six full scale tests with front and rear ES-2: two EU, two 214, & two side NCAP tests
- Thirteen torso & pelvis biofidelity sled tests & limited repeatability

- Three 214 tests/IIHS barrier
- Eight 201P pole comparison tests: ES-2 versus SIDH3
- Component tests: back plate interaction, flat top
- Sled tests: head/neck/shoulder biofidelity & kinematics

- TBD- Eight 214/NCAP tests with current vehicles for fleet performance

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ES-2 and Flat-Top

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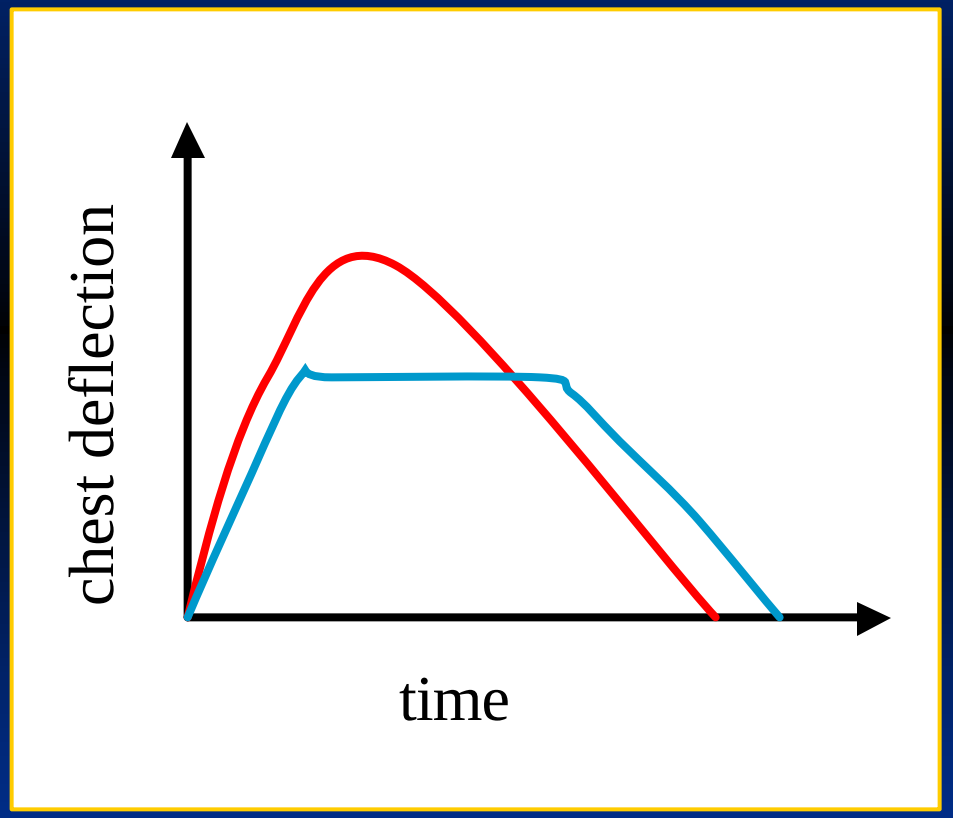
- Flat-top is a period of constant rib deflection over time.
- Flat-top is merely evidence that the ribs and the spine are moving at the same velocity relative to ground.
  - Flat-top is not necessarily evidence of rib binding.



"High Mass" Impactor Tests

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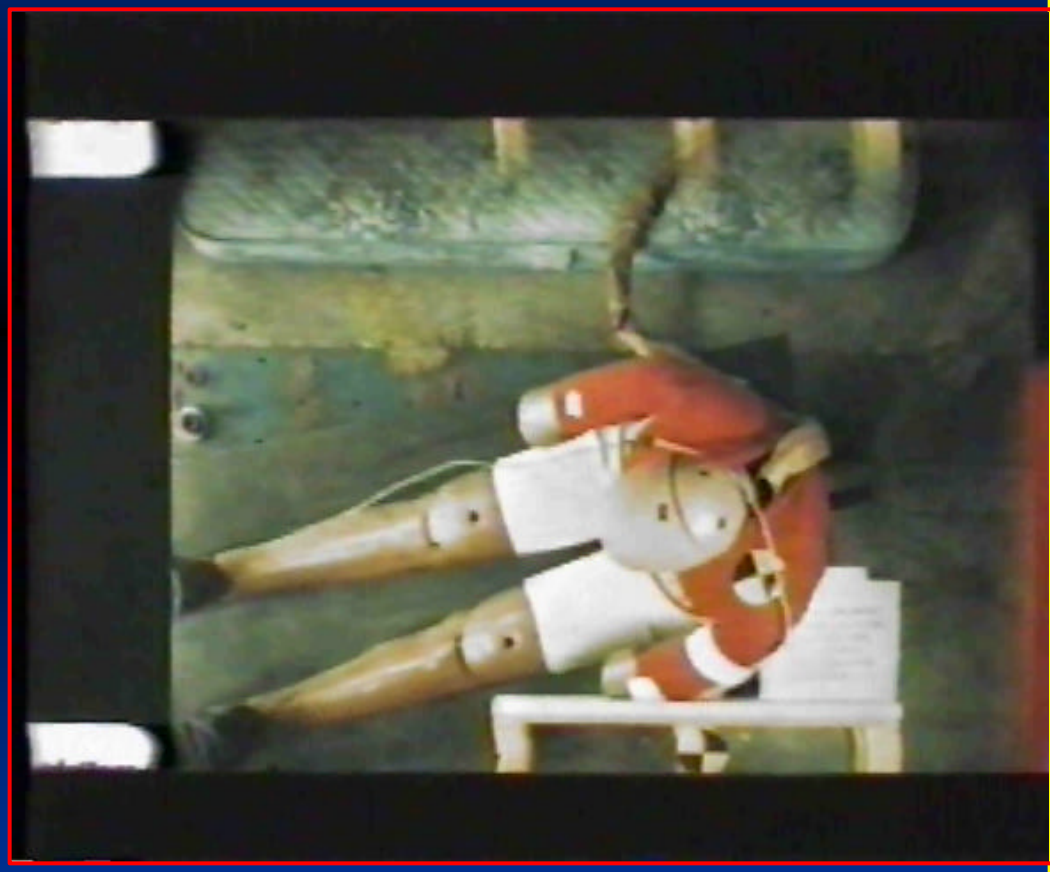
NHTSA Side Impact Research

- Impactor: 907 kg at 5 m/s contacting the thorax and abdomen
- Test conditions: Impactor contacted the ES-2 at angles of 0, +10, +20, and -10 in the horizontal plane
- ES-2 rib modules designs: coated piston, ball and needle bearings



"High Mass" Impactor Tests - Results

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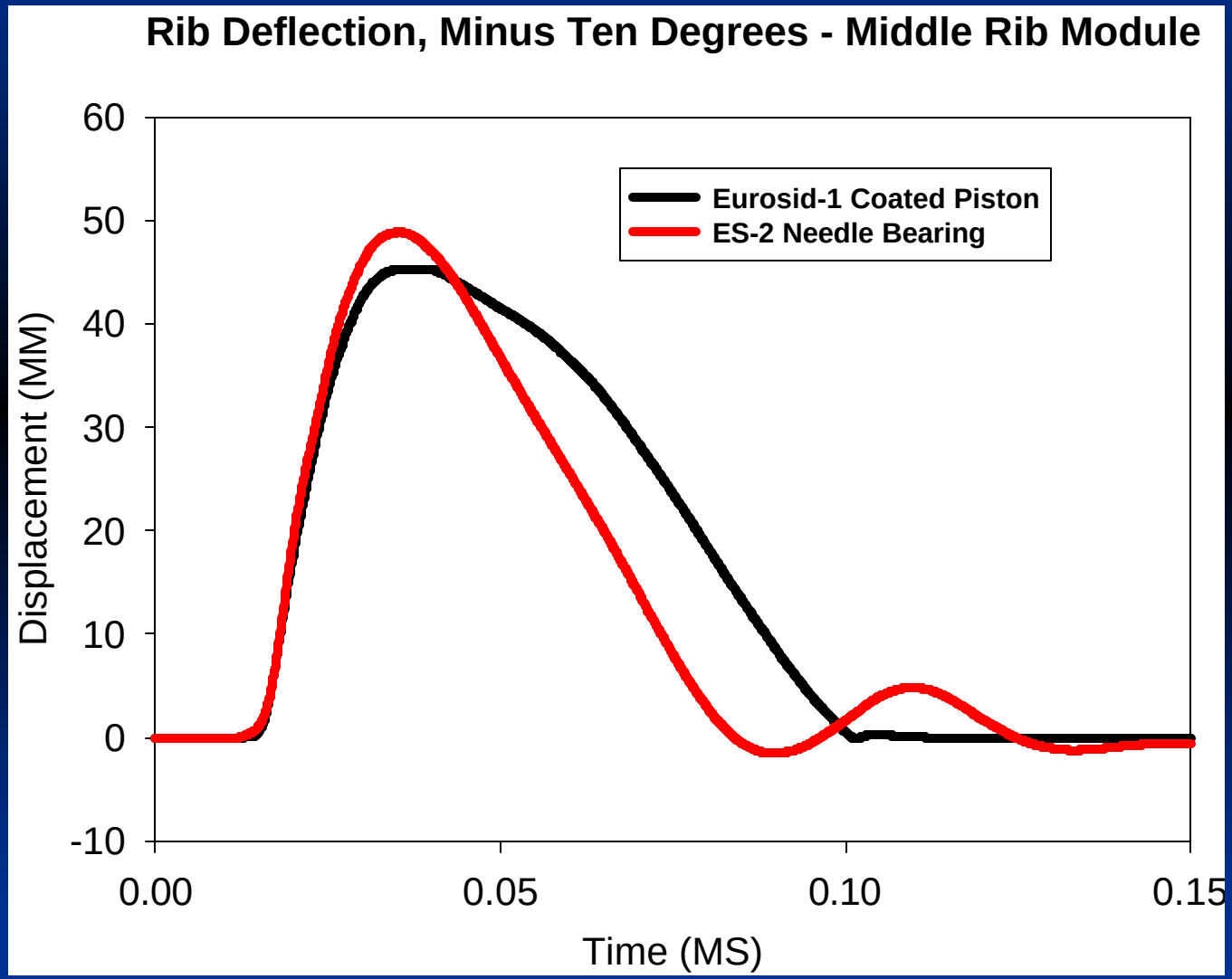
- **No evidence of flat-top in ES-2 needle bearing rib modules**
- **Higher deflections in ES-2 compared to Eurosid-1**

High-mass Pendulum Tests



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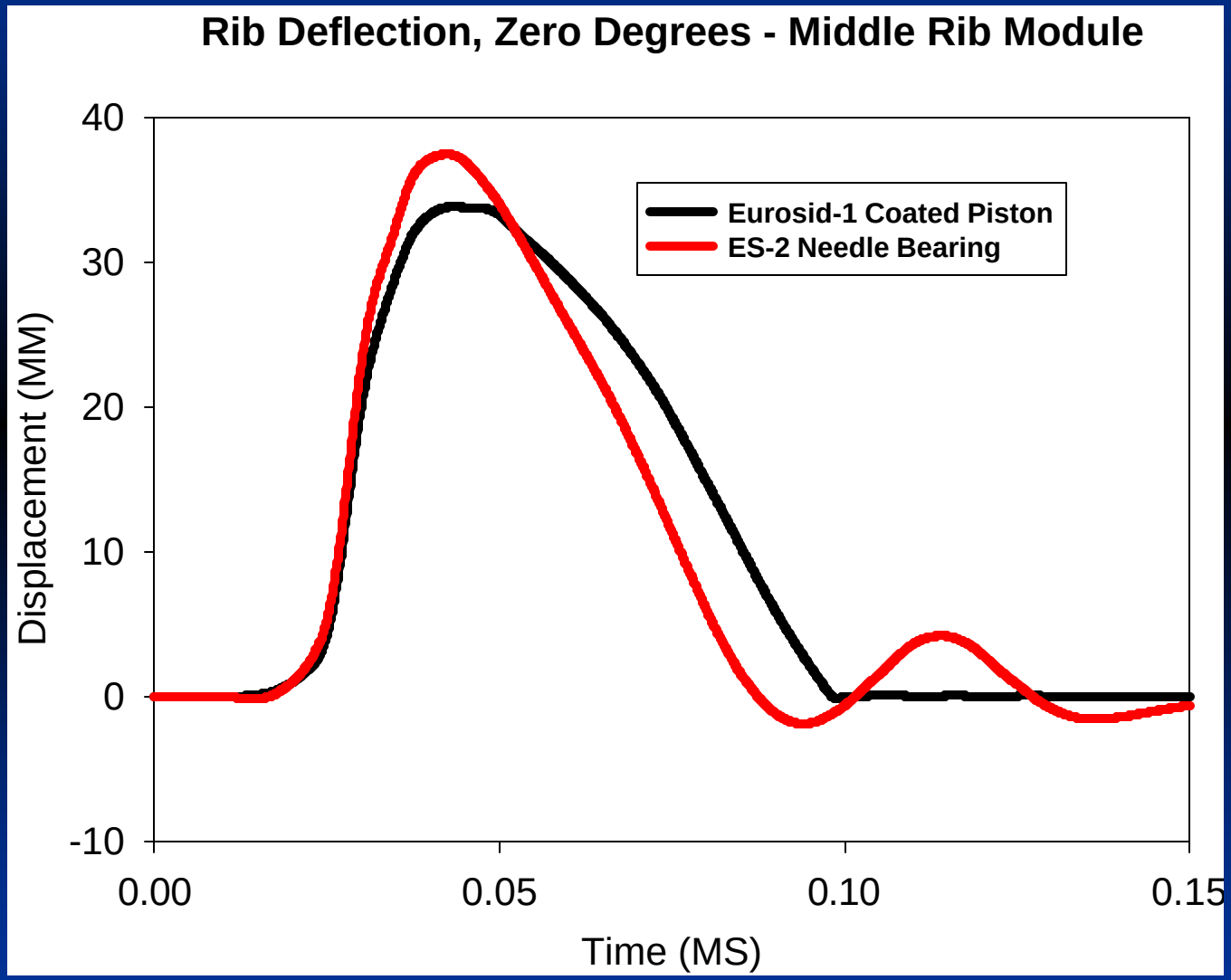

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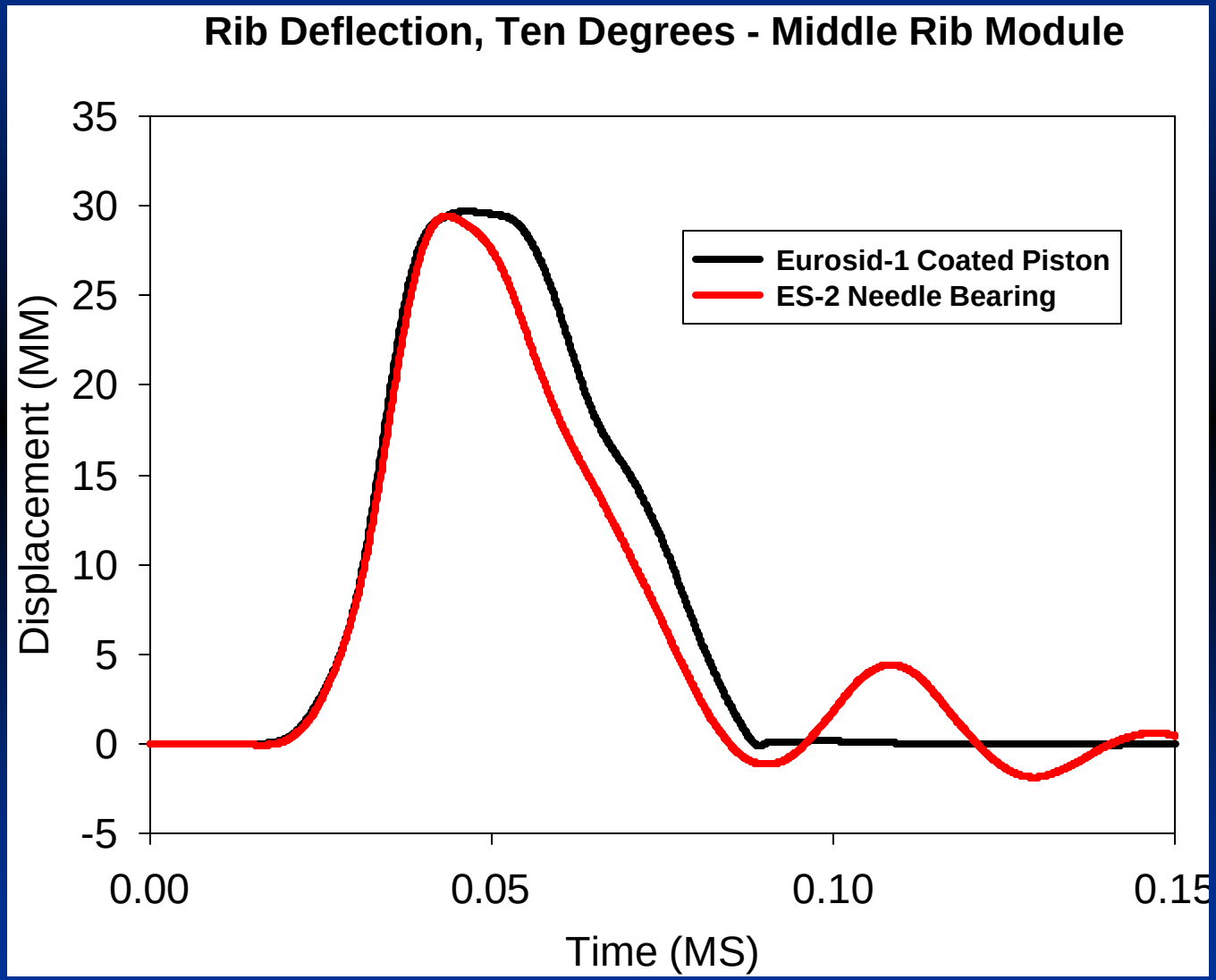

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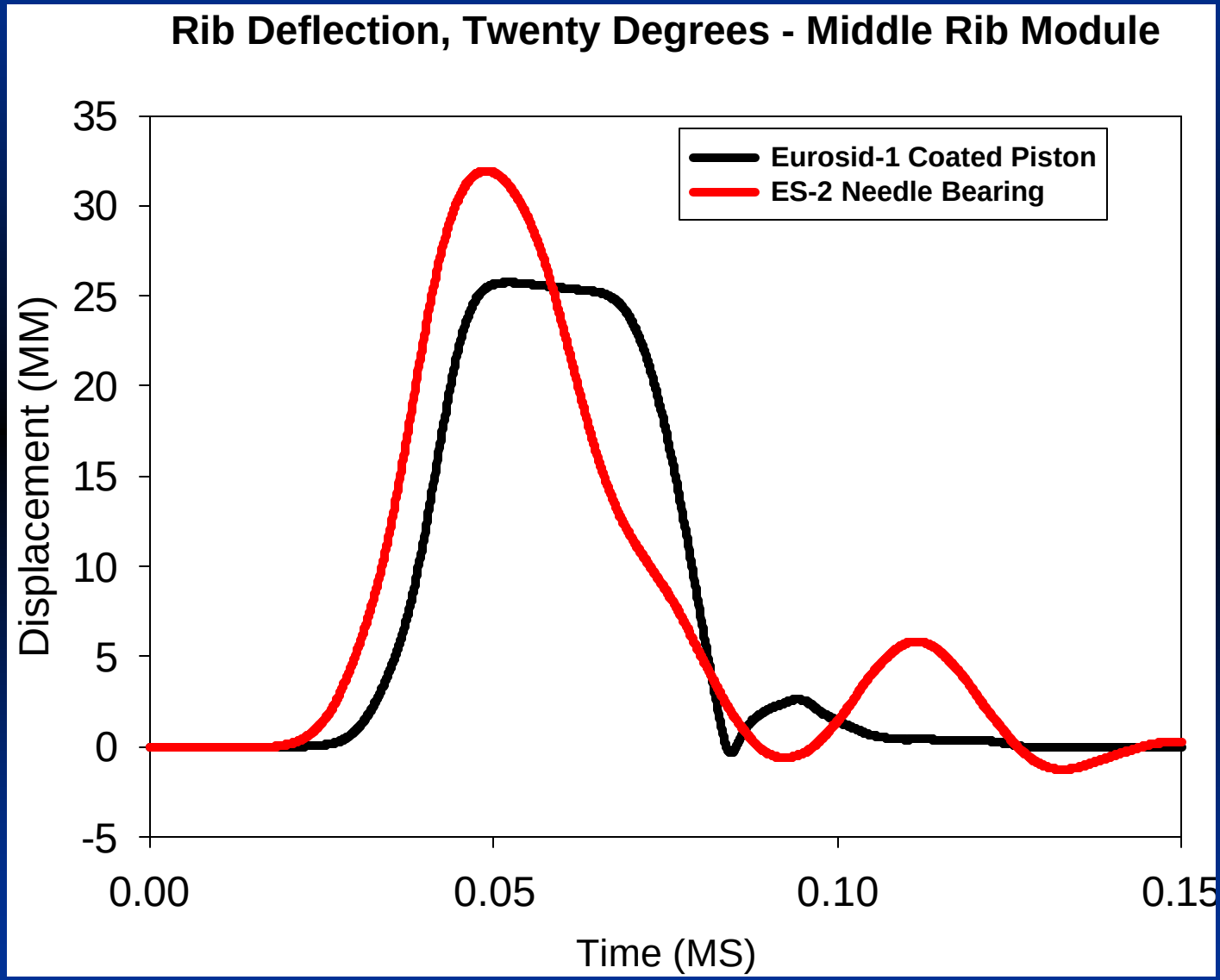

ES-2 Phase I Full Scale Tests

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NHTSA Side Impact Research

VEHICLE	DUMMY	TEST CONFIGURATION	SPEED (km/h)
96 Taurus- 4dr*	Eurosid-1	EU Side	48.3
96 Taurus- 4dr	ES-2	EU Side	49.2
95 Metro- 3 dr*	Eurosid-1	EU Side	50.3
96 Metro- 3 dr	ES-2	EU Side	50.5
96 Taurus- 4dr	ES-2	FMVSS 214	53.3
96 Taurus- 4dr	ES-2	FMVSS 214	52.3
98 Chevy Cavalier- 4dr	ES-2	US Side NCAP	61.6
2000 Grand Am- 2dr	ES-2	US Side NCAP	62.1

** Baseline Tests in 1997*

ES-2 Phase I Full Scale Tests

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96 Taurus- 4dr	ES-2	FMVSS 214	53.3
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** Baseline Tests in 1997*

Full Scale Test Rib Responses EU Tests: ES-2 Versus Eurosid-1

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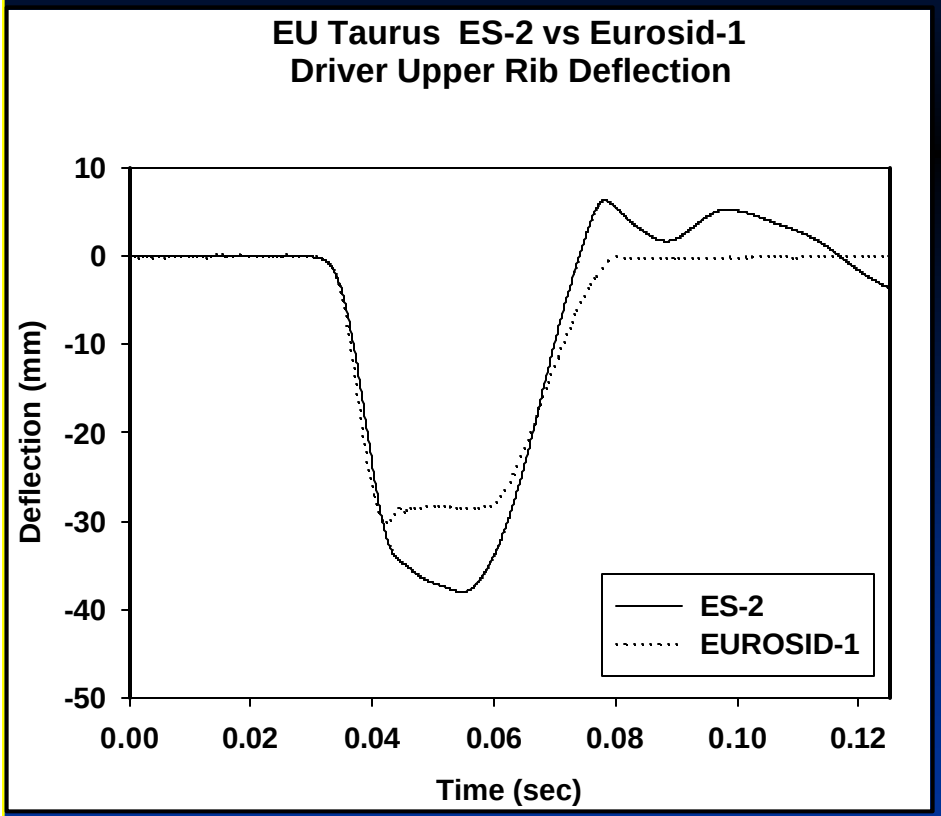
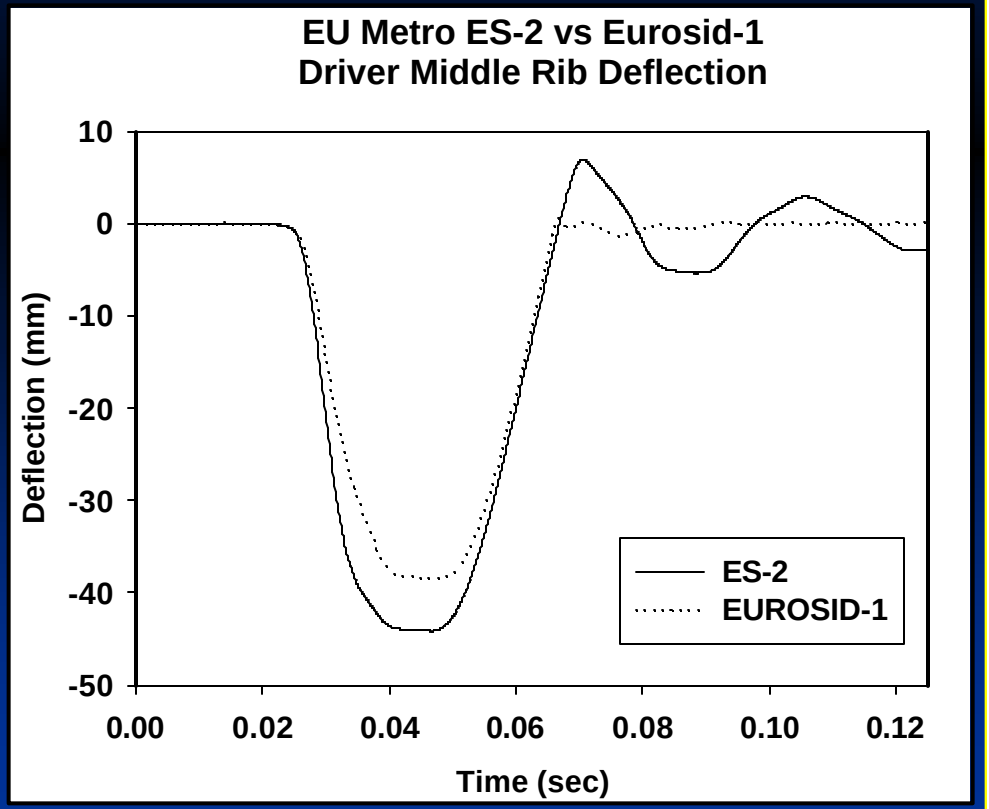
NHTSA Side Impact Research

- Deflection flat tops reduced but still present for ES-2
- Higher deflection for ES-2





Full Scale Test Rib Responses EU Tests: ES-2 Versus Eurosid-1

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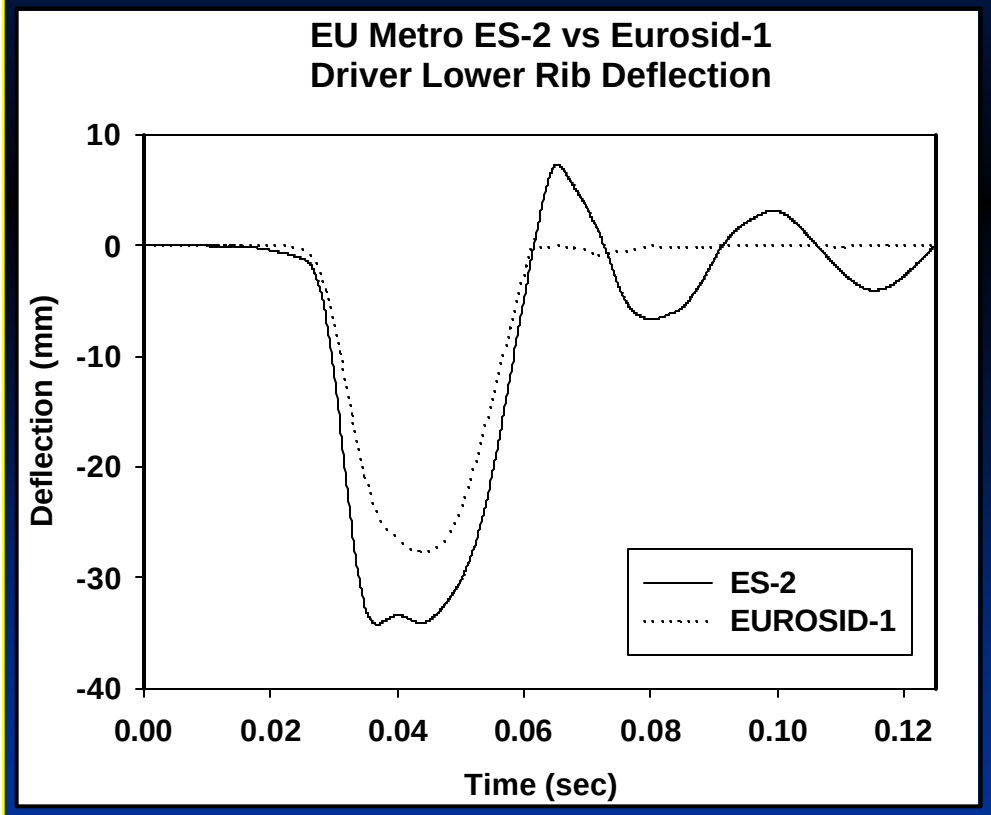
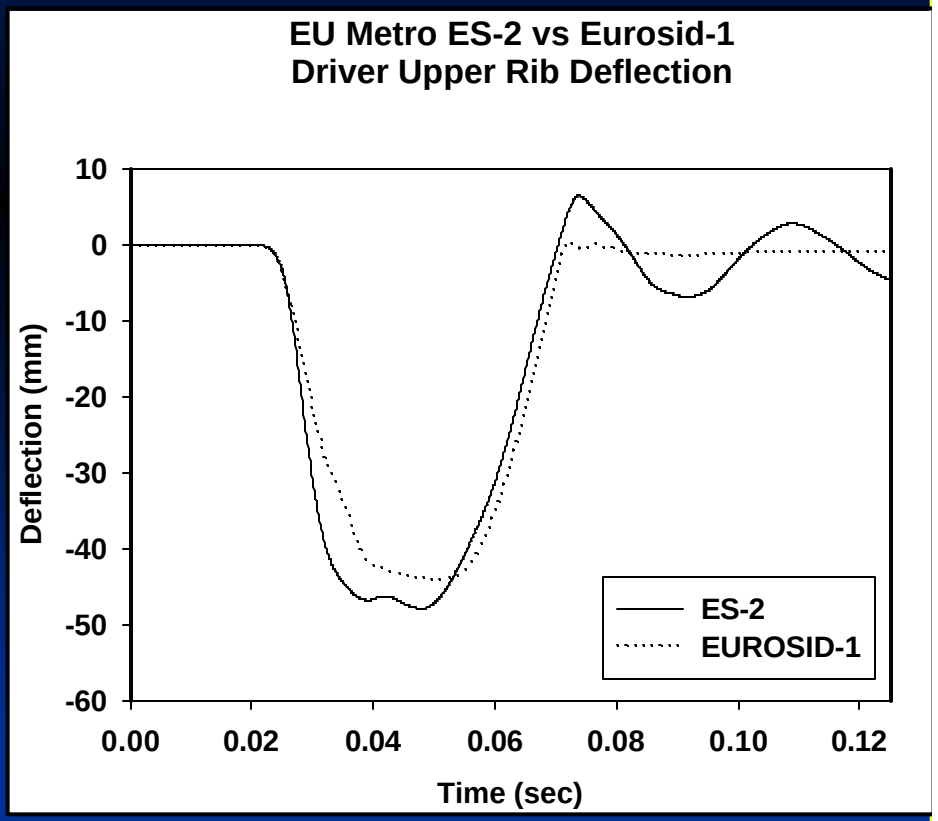
NHTSA Side Impact Research

- Post-event oscillations in most rib deflections and minor oscillations near main event in a few deflections





Full Scale Test Rib Responses 214/Side NCAP Tests: ES-2

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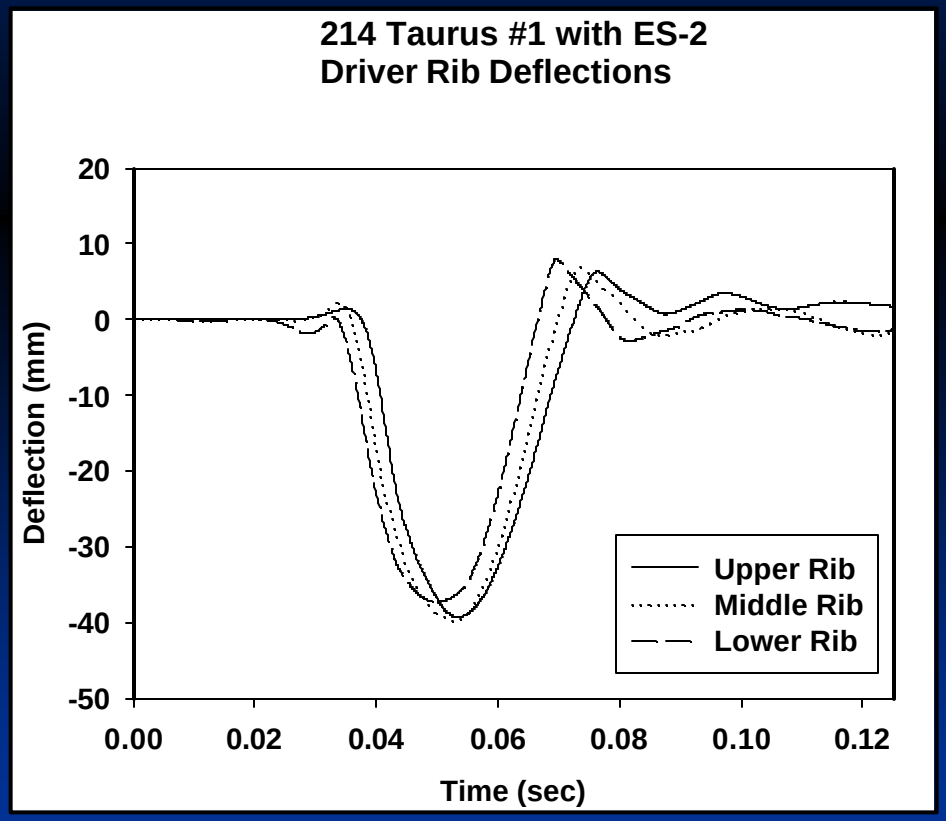
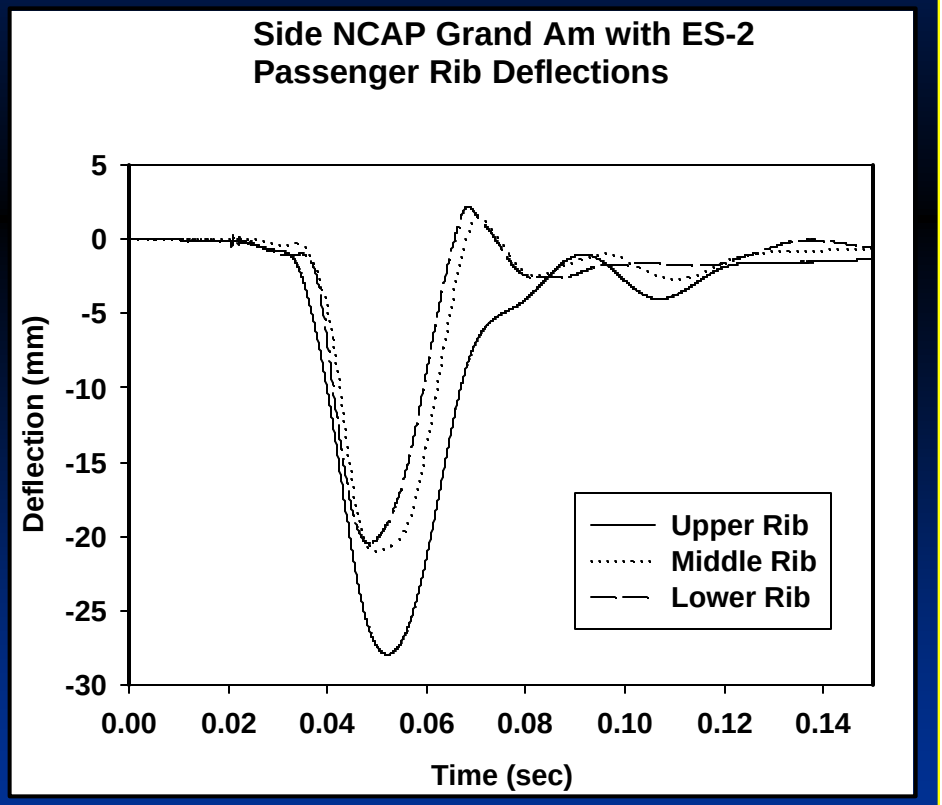
NHTSA Side Impact Research

- With one "exception" deflection flat tops not present





Full Scale Test Rib Responses 214/Side NCAP Tests: ES-2

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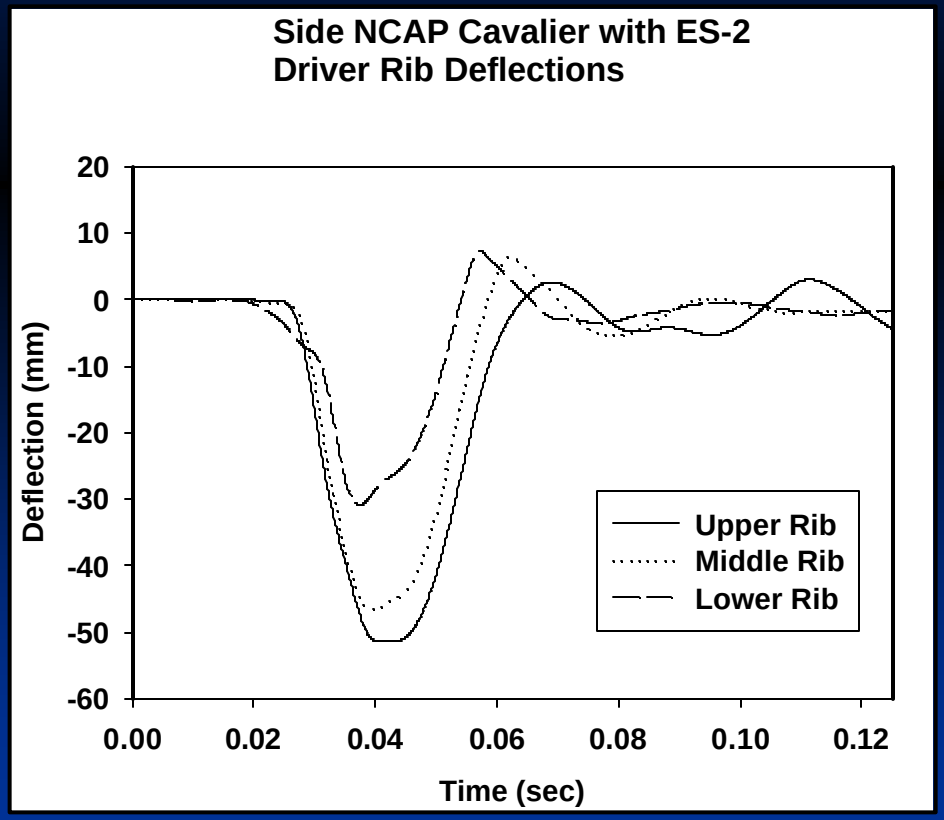
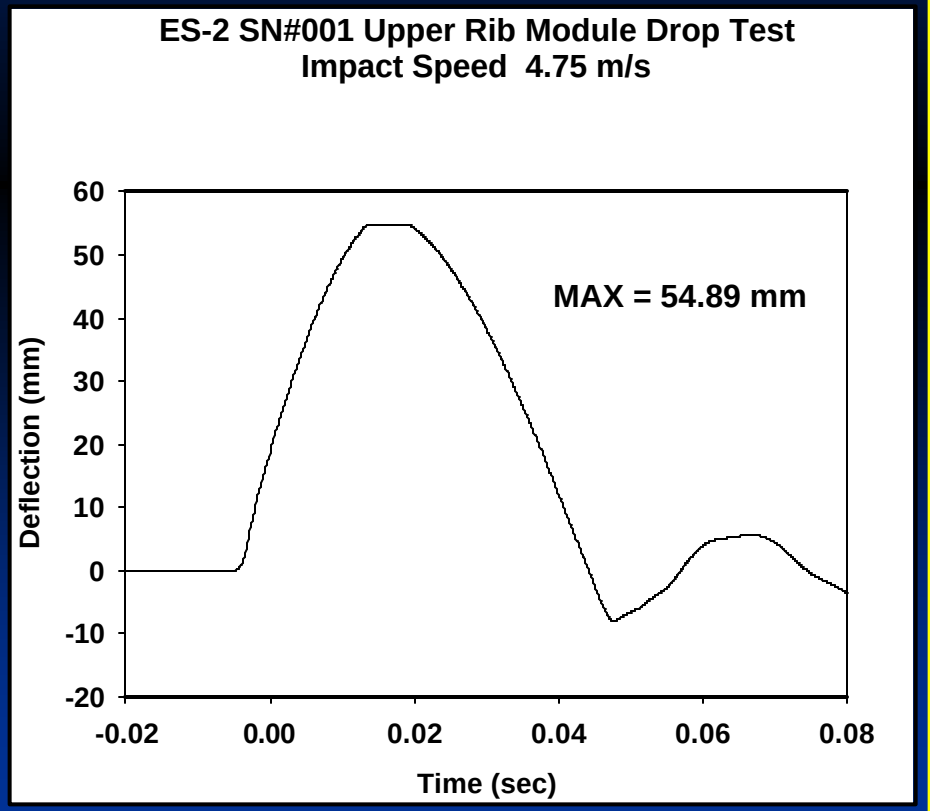
NHTSA Side Impact Research

- One rib deflection (of 24) exhibited flat top behavior … close to full dynamic range of rib module.





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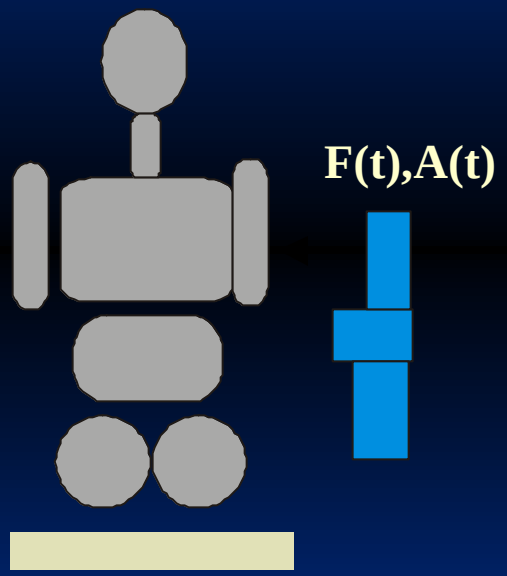
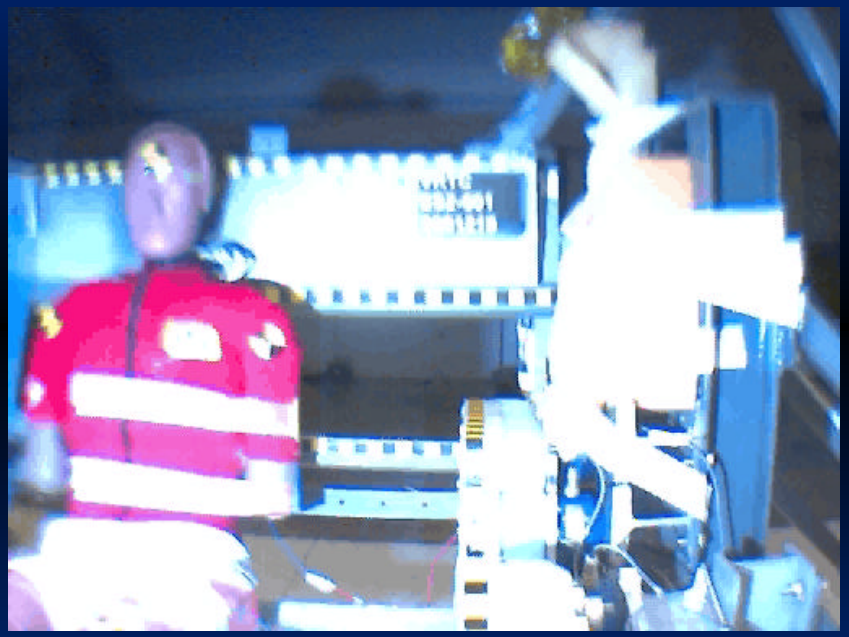
Biofidelity – What is Important?

- **First and foremost, a dummy should interact with the vehicle environment in a human-like manner.**
  - **Human-like force-area-time histories between occupant and vehicle.**
- **Secondly, those measures necessary to calculate injury criteria should be similar to the same measures on the human.**

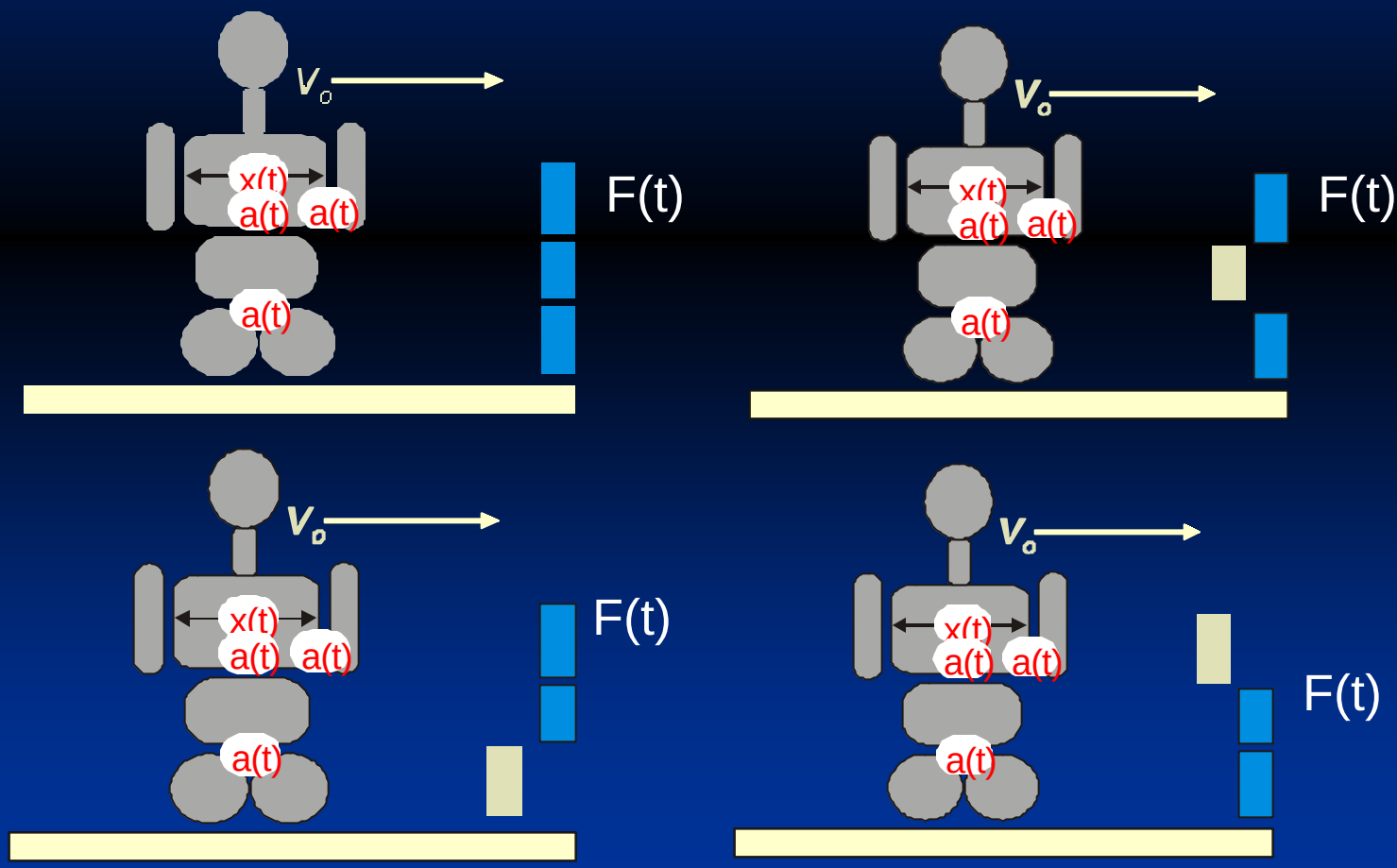


IHRA Side Impact Torso and Pelvis Sled Test Requirements

- Shoulder to Pelvis evaluation
- Based upon 45 NHTSA sponsored cadaver tests
- Two door speeds - 6.7 and 8.9 m/s (15 and 20 mph)
- Two door stiffnesses - Padded and rigid
- Four door surface geometries

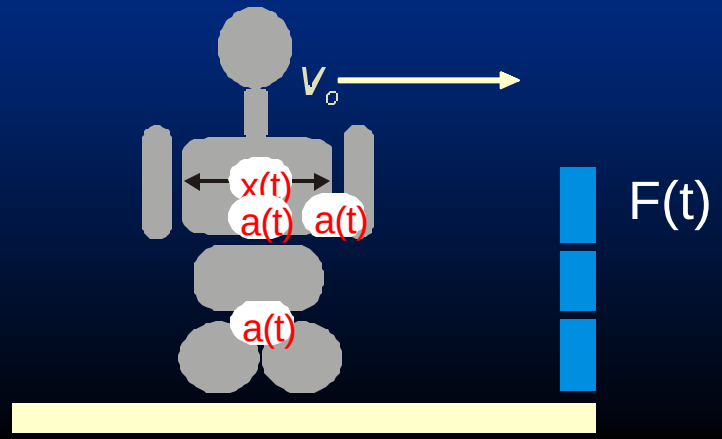


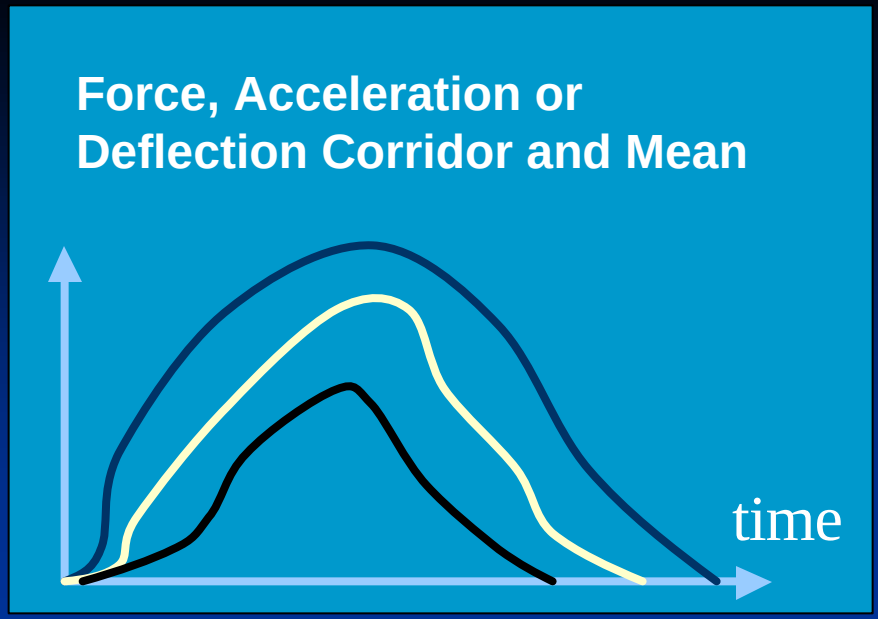
IHRA Side Impact Sled Test Load Wall Geometry



IHRA Side Impact Sled Requirements

- Door Forces at the thorax, abdomen, pelvis and legs
- Deflection of the upper and lower thorax, and mid abdomen.
- Acceleration – spine, pelvis and ribs



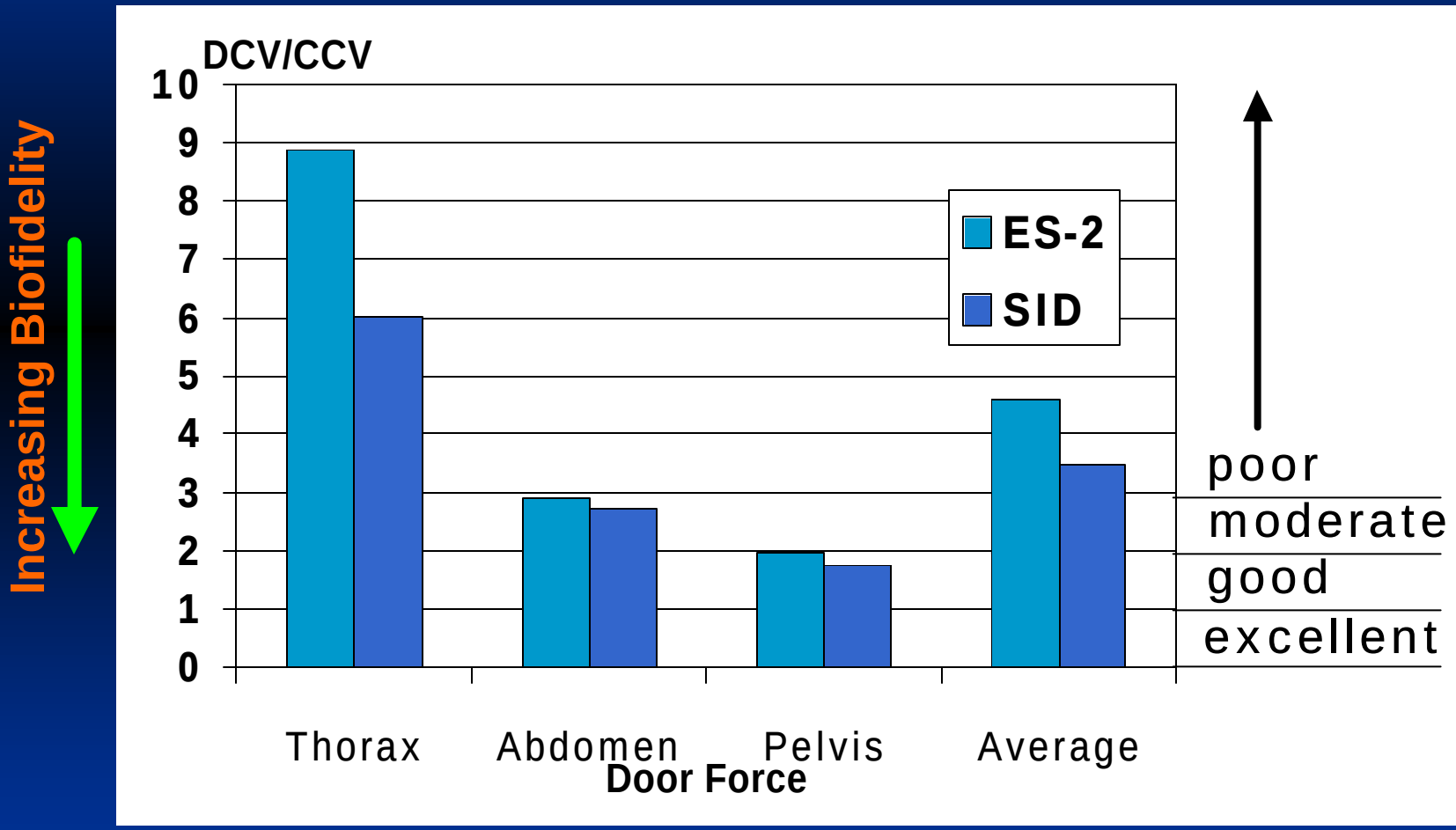


Rating Dummy Biofidelity - DCV/CCV Ratio

0 <= DCV/CCV <1	Excellent - Dummy is less variant than the cadaver sample.
DCV/CCV = 1	Excellent - Dummy is as variant as the cadaver sample.
1 < DCV/CCV <=2	Good - Dummy is between one and two times as variant as the cadaver sample.
2 < DCV/CCV <=3	Moderate - Dummy is between two and three times as variant as the cadaver sample.
N < DCV/CCV <= N+1	Poor - Dummy is between n and n+1 times as variant as the cadaver sample.

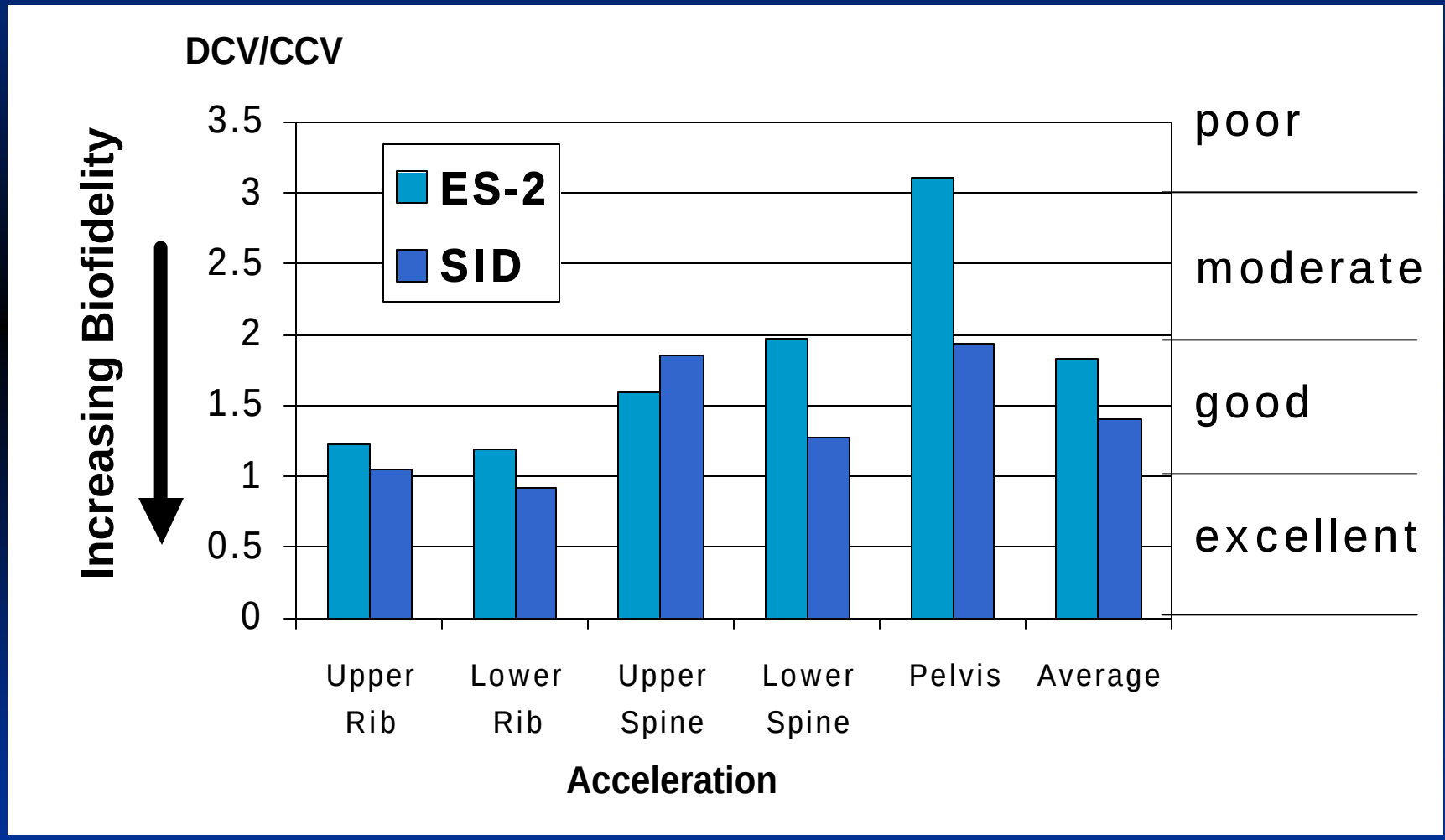
Marcus et al 1986

Results - Door Force DCV/CCV Ratio



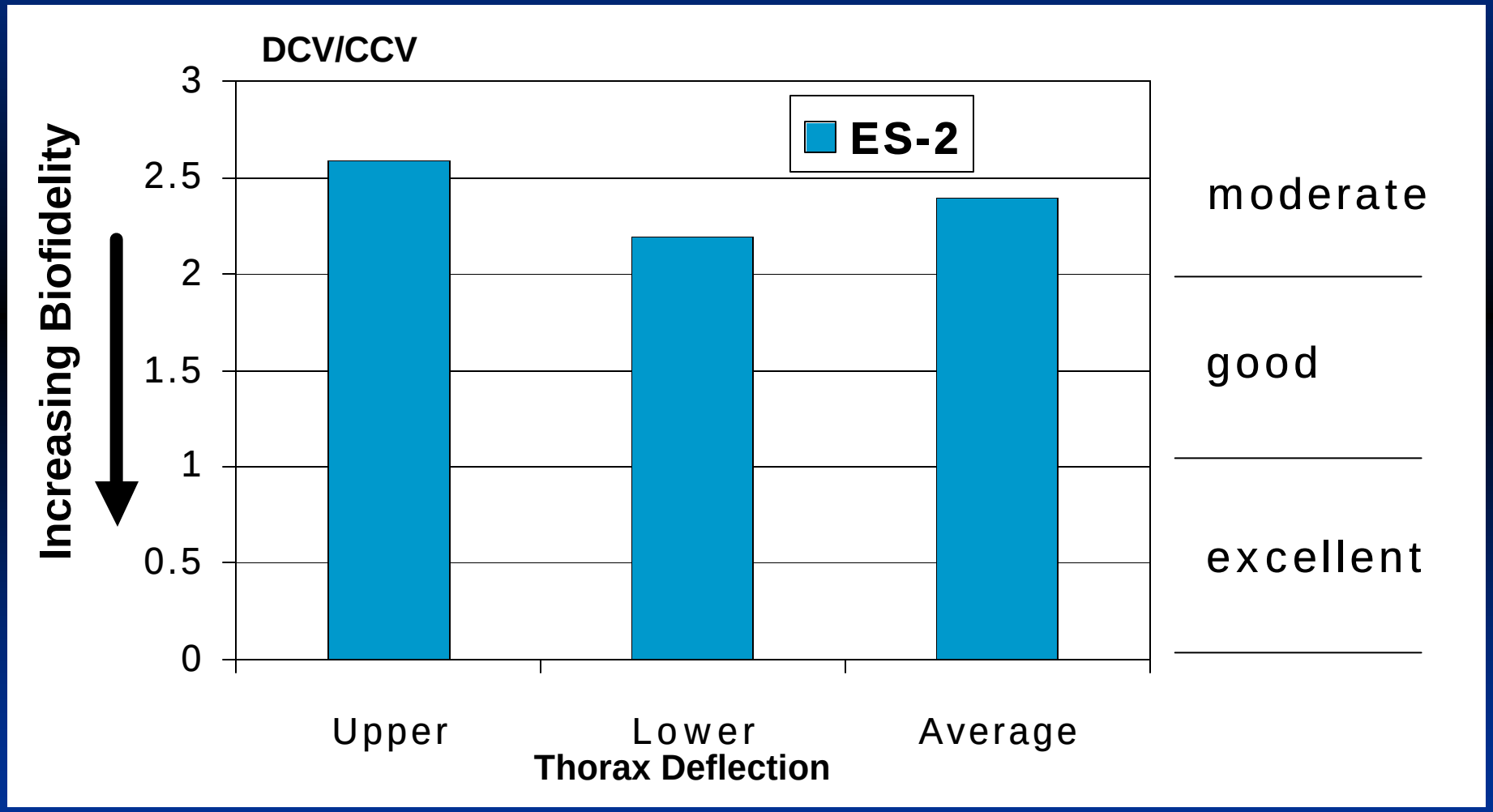
Samaha et al 2001 ESV

DCV/CCV Ratio – Acceleration



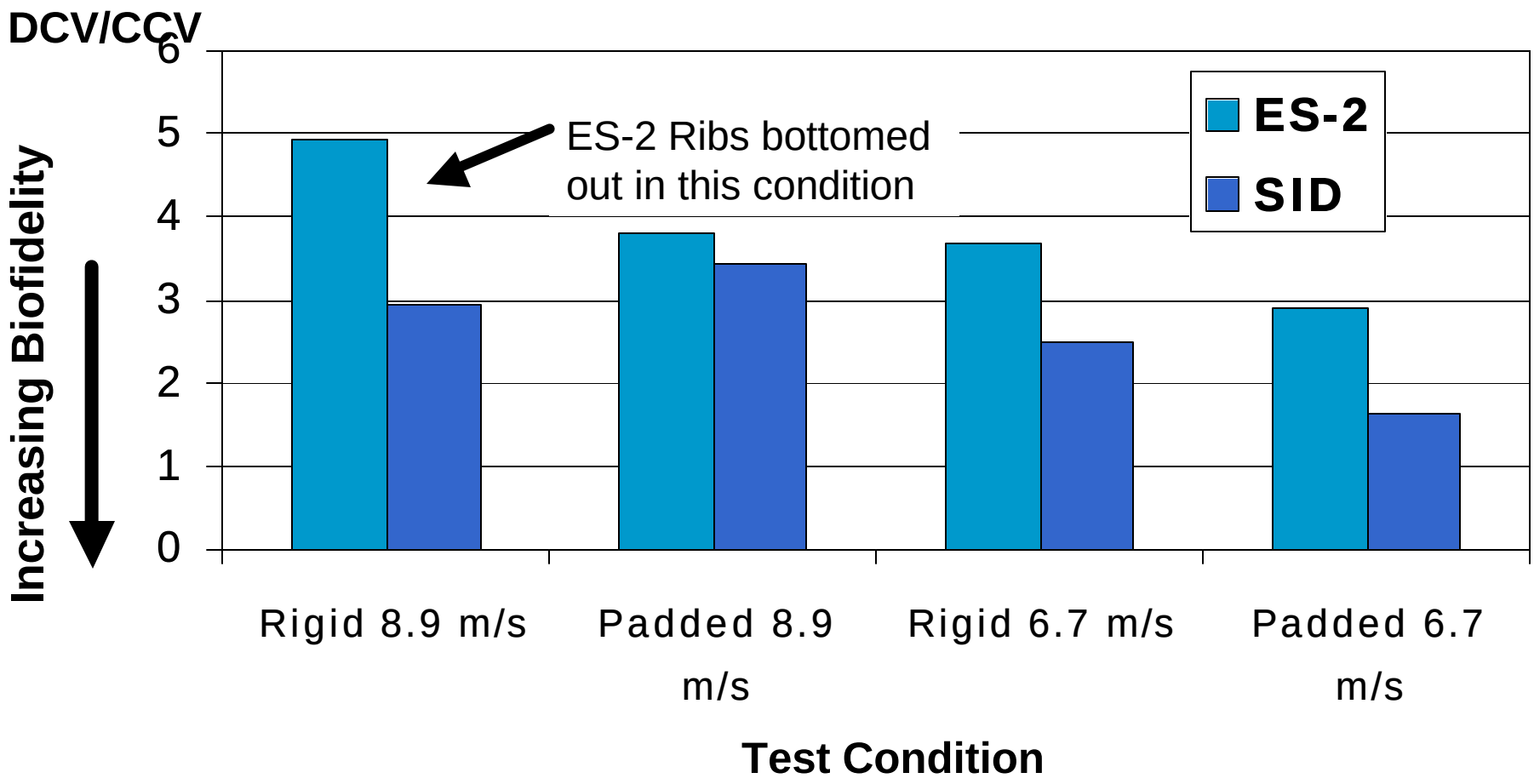
Samaha et al 2001 ESV

DCV/CCV Ratio – Deflection



Samaha et al 2001 ESV

DCV/CCV Ratio vs. Test Condition



Samaha et al 2001 ESV

Previous work - ISO Biofidelity Ratings

Note: Larger numbers indicate better biofidelity.

	Eurosid-1	SID
Head	3.33	0.0
Neck	3.70	2.55
Shoulder	3.90	0.0
Thorax	4.78	5.02
Abdomen	3.23	4.38
Pelvis	1.76	2.76
Overall	3.22	2.78

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Comparison of ES-2 and SID/H3 Instrumentation

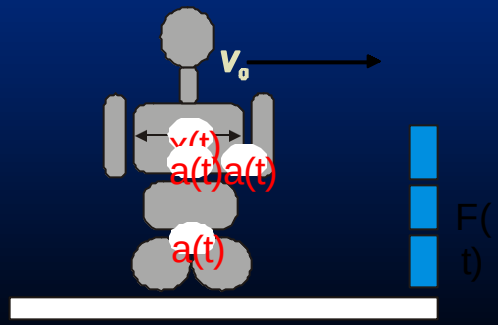
	Measurement	ES-2	SID/HIII
Head	9 accel Array	U	U
Neck	Upper Loads	U	U
	Lower Loads	U	U
Shoulder	Load/Rotation	U	

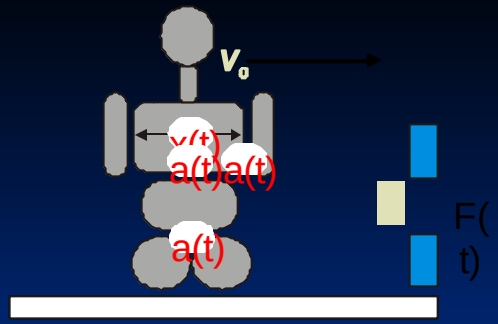
Comparison of ES-2 and SID/H3 Instrumentation

	Measurement	ES-2	SID/HIII
Thorax	Deflection	U	U
	Acceleration	U	U
Abdomen	Force	U	
Pelvis	Acceleration	U	U
	Force	U	

ES-2 Torso Injury Assessment Capability Compared to SID

- Compare SID and ES-2 instrumentation output in flat wall and abdominal offset conditions
- Correlate instrumentation output with injuries in similar cadaver tests





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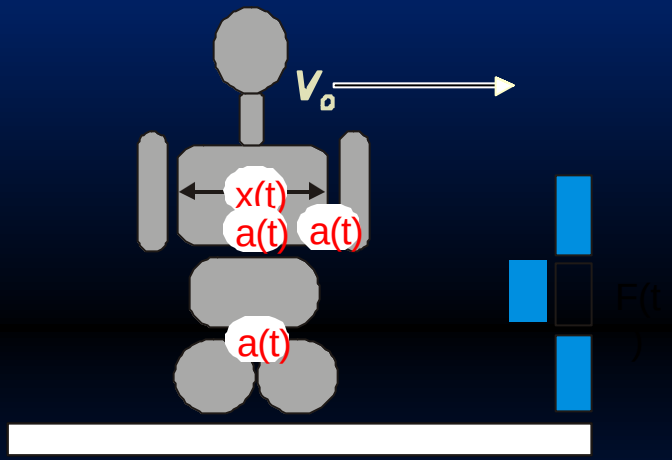
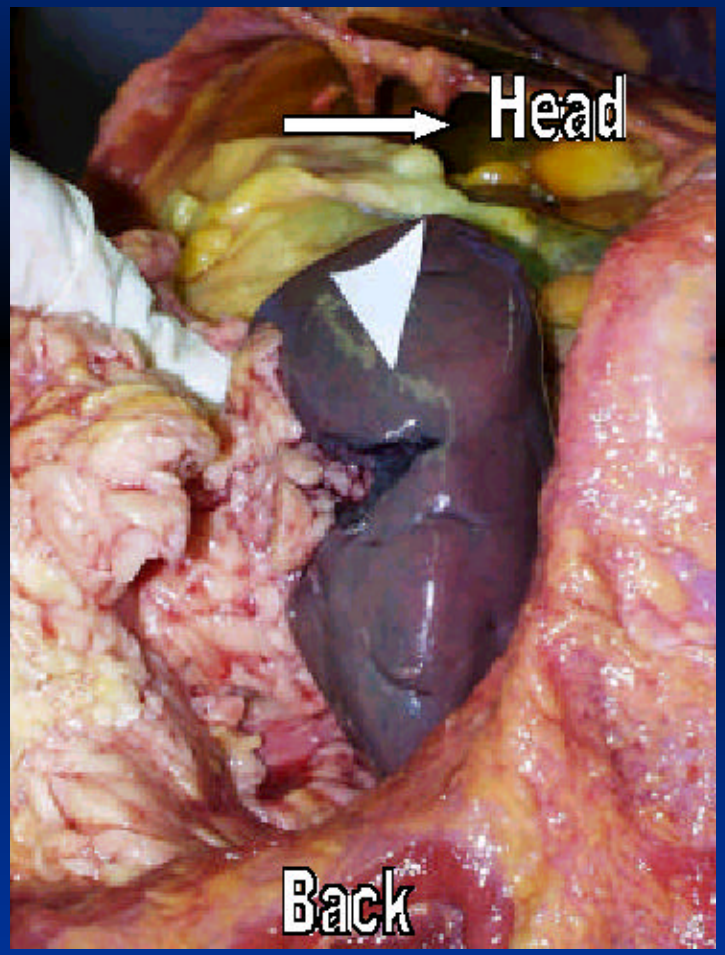
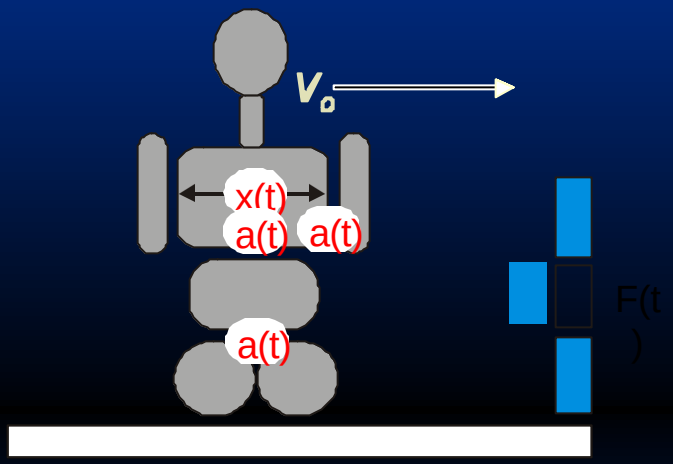
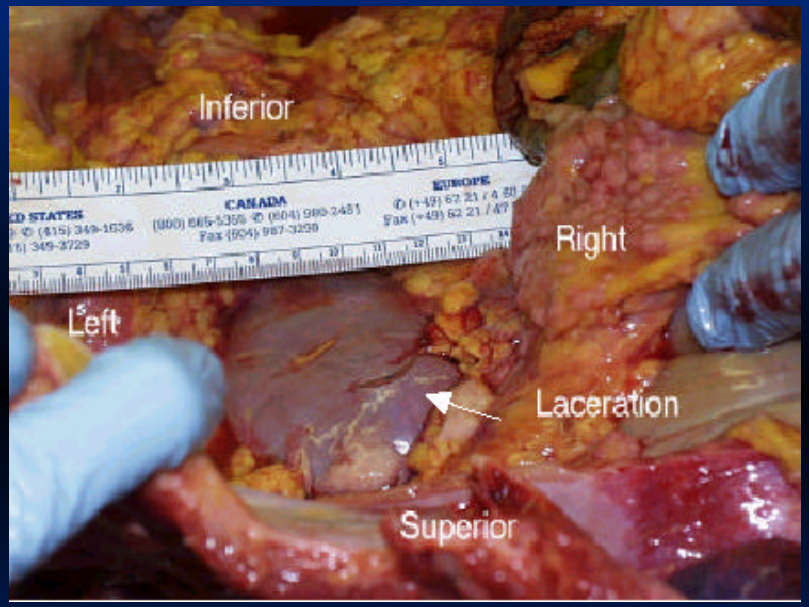




- Cadaver Test B4218
  - AIS 4 Kidney Laceration
  - 5 fractured Ribs

ES-2 Torso Injury Assessment Capability Compared to SID





- Cadaver Test B4268
  - AIS 3 Kidney Laceration
  - 7 fractured Ribs

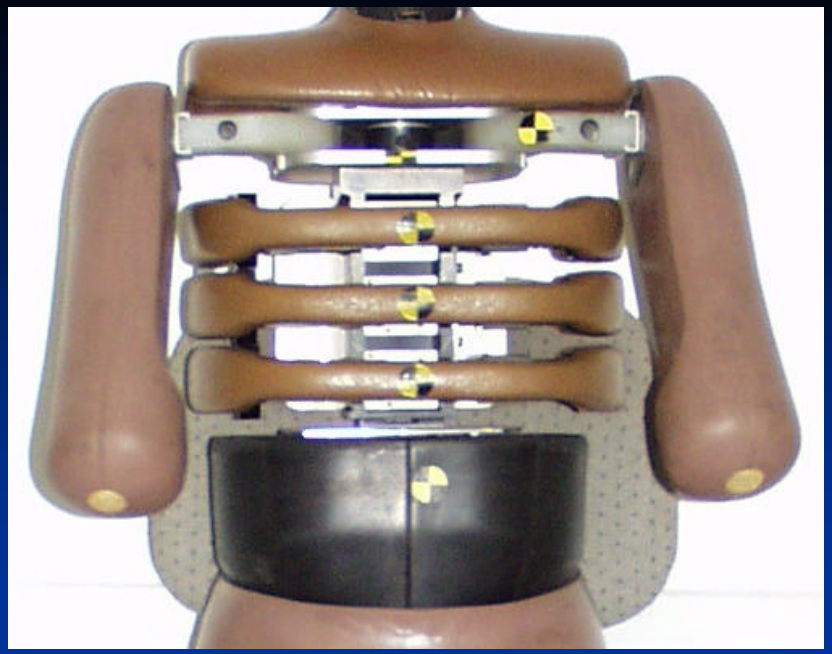
ES-2 Torso Injury Assessment Capability Compared to SID

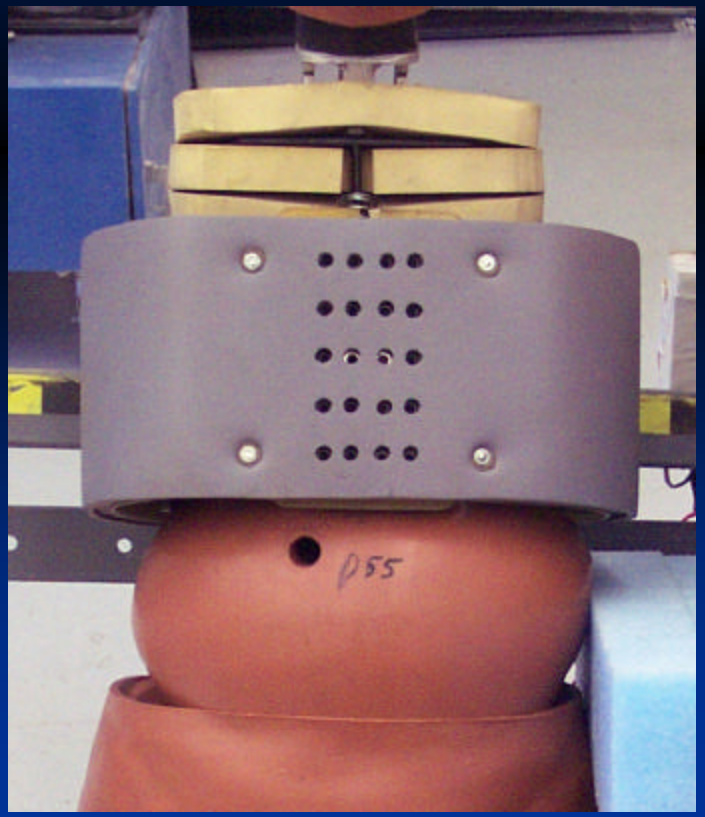
		Flat Wall	Abdominal Offset
SID	TTI (85 g)	71 g	52 g
	Pelvis Acceleration (120 g)	67 g	53 g
ES-2	Chest Deflection (42 mm)	52 mm	31 mm
	Abdominal Force (2500 N)	1402 N	8585 N

Cadaver Autopsy Results		
Fractured Ribs	7	6
Soft Tissue	None	Kidney Laceration

ES-2 Torso Injury Assessment Capability Compared to SID

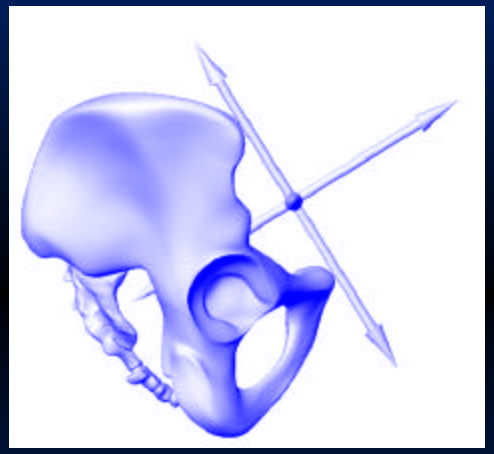
- **Conclusion - ES-2 abdominal load measurement capability detects injuries the SID misses.**

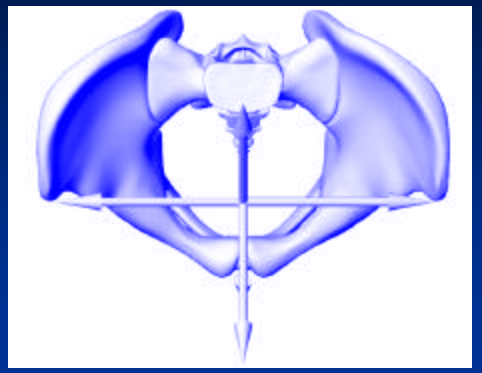




ES-2 Pelvis

- **ES-2 measures Pelvis Acceleration and Pubic Symphysis Load (PSL), while SID only measures acceleration**
- **PSL may be a better measure of the load which is directed into the hip joint, and thus may be a better predictor of serious pelvic injury.**





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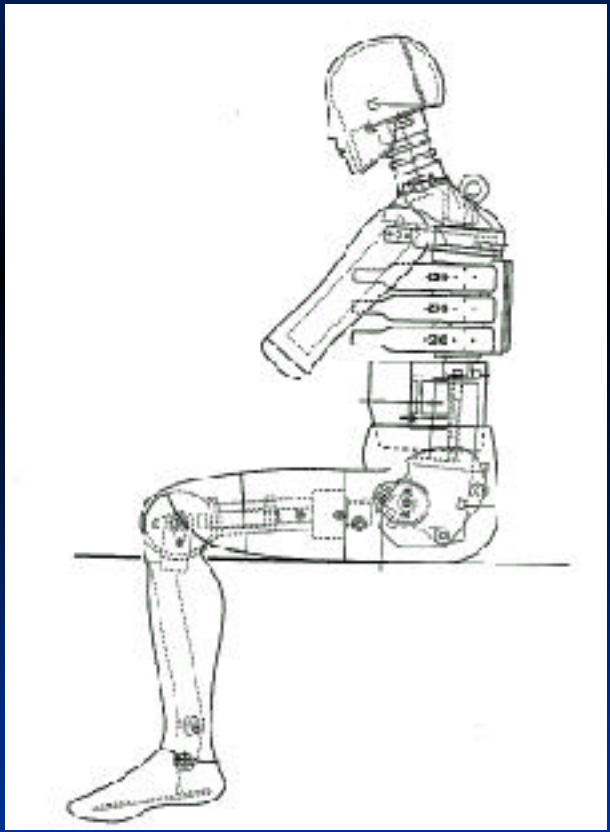
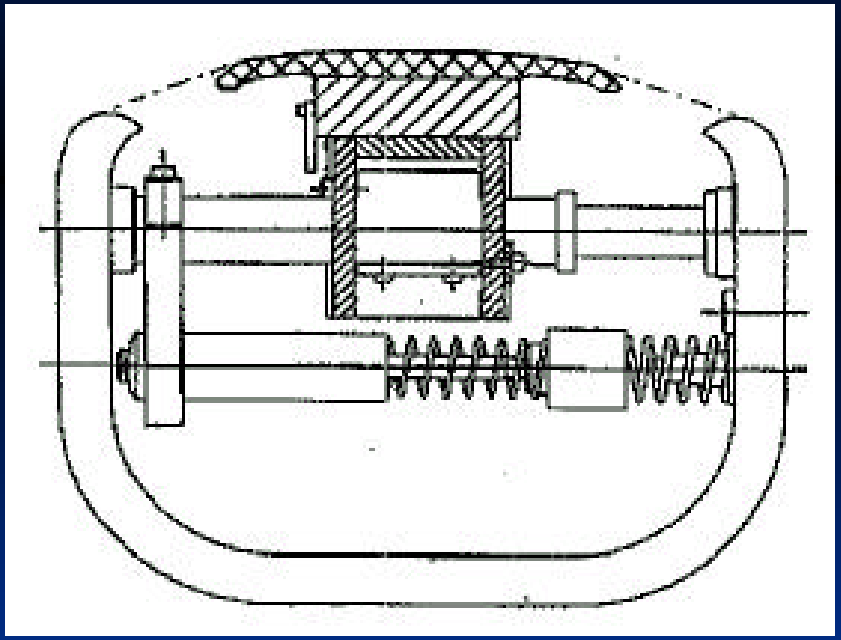
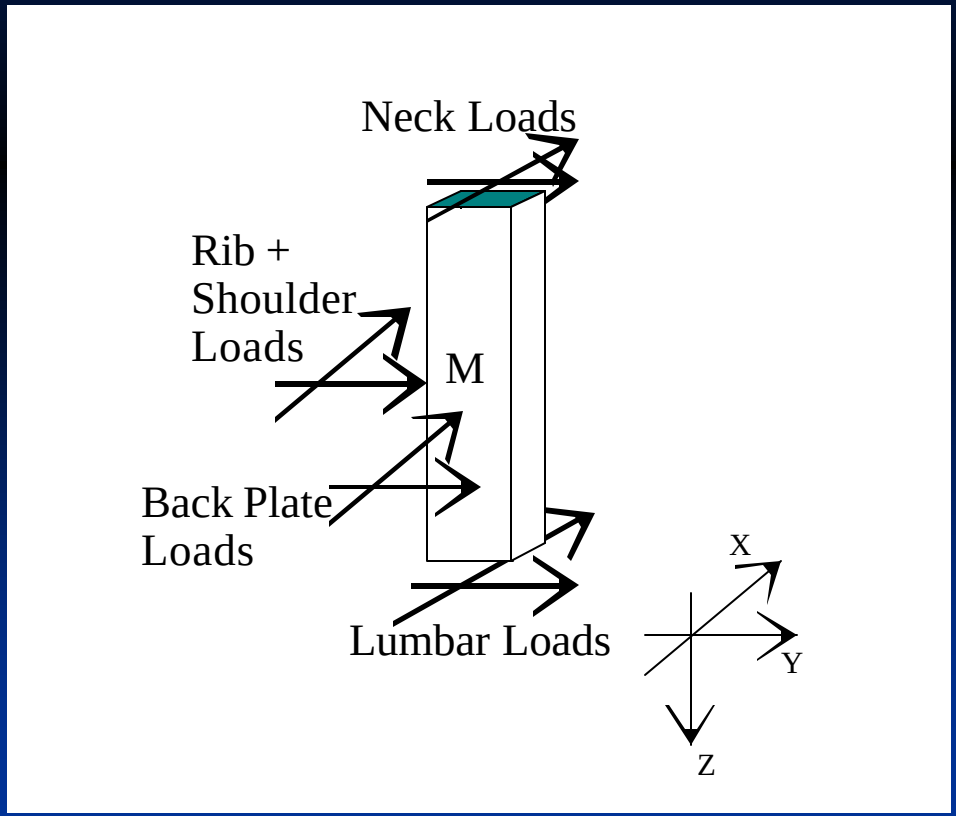
ES-2 Back-plate



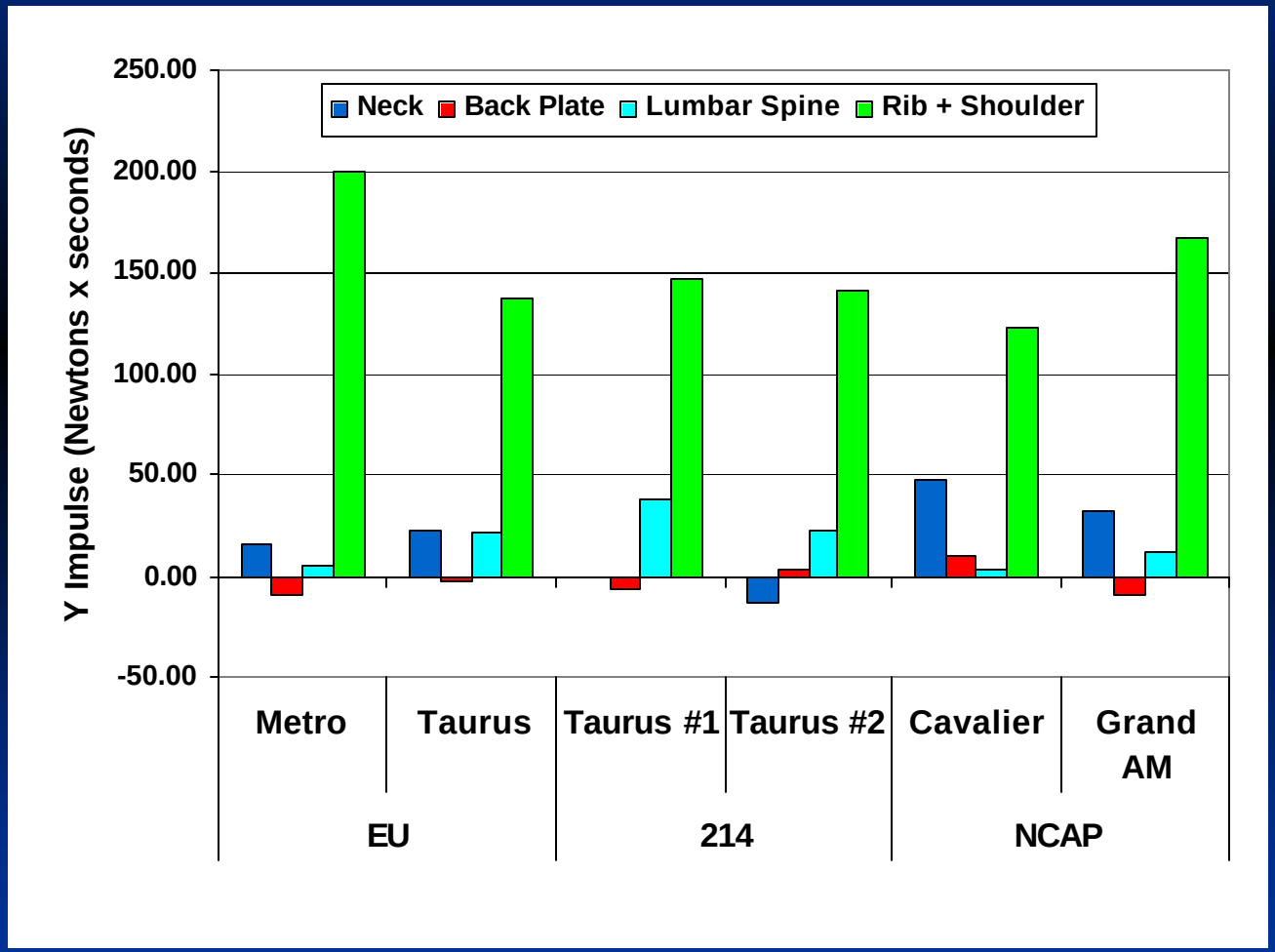


ES-2 Back-plate

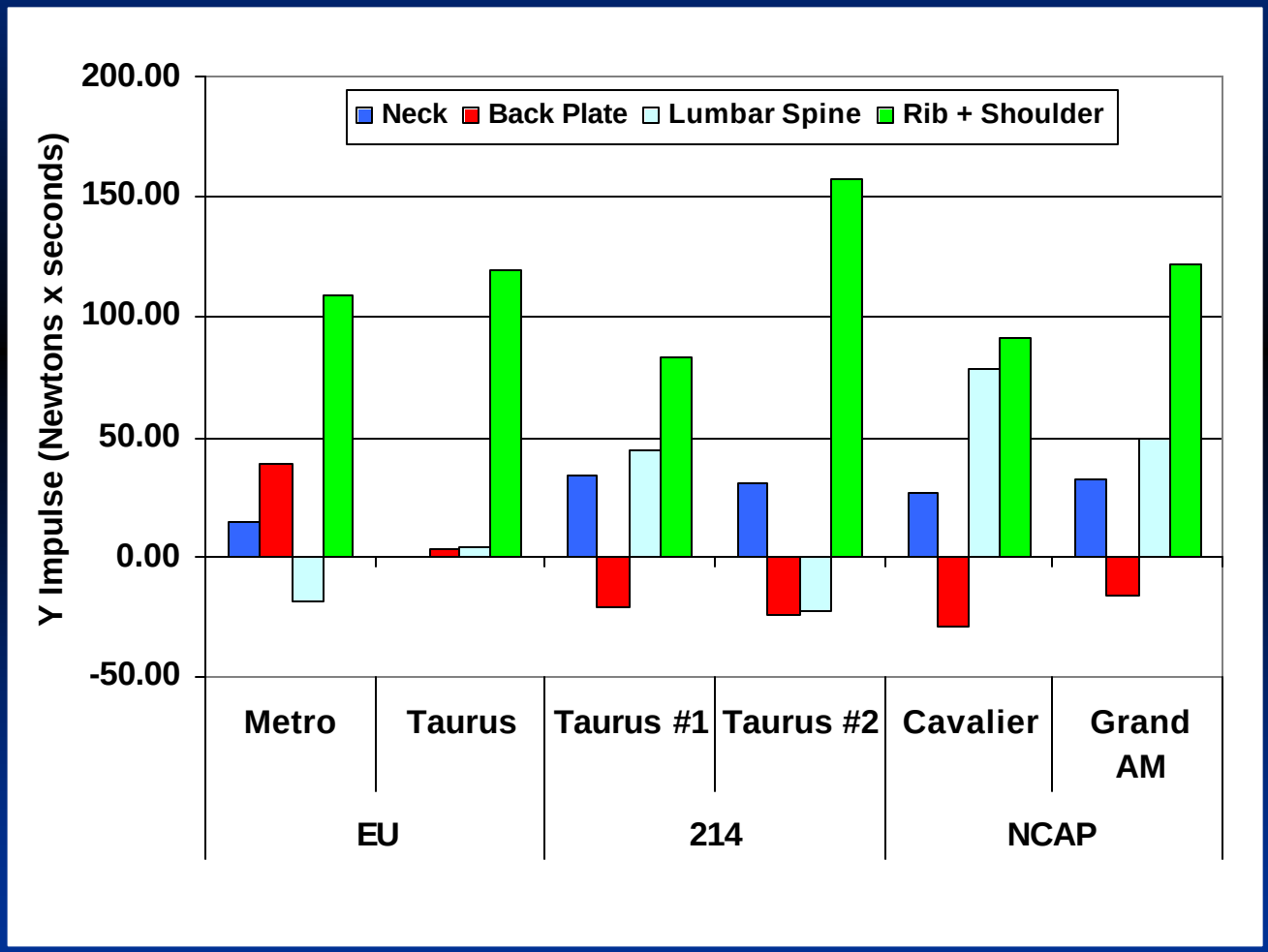
- **Force Balance on ES-2 Spine**



Full-Scale Vehicle Test – Driver Impulse Analysis



Full-Scale Vehicle Test – Passenger Impulse Analysis



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Conclusions

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- The ES-2 thorax is less biofidelic than the SID while the ES-2 abdomen and pelvis biofidelity are roughly equivalent.
- ES-2 detects abdominal injuries that the SID misses.
- ES-2 has the potential to better detect serious pelvic injuries.
- More research is necessary to understand the biofidelity of the head/neck complex.
- ES-2 modifications appear to have addressed rib binding which is one mechanism of rib deflection flat top.
- Loads from the seat back through the ES-2 back plate transfer little momentum to the spine of the dummy.

Additional ES-2 Research

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- Additional component/sled tests to provide a assessment of head/neck/shoulder biofidelity and kinematics (summer 01)
- Additional component test to ensure that the ES-2 ribs are not binding and that the dummy is repeatable (summer 01)
- Component tests to assess back plate interaction with the seat back (summer 01)
- Application of injury criteria for the ES-2 dummy (summer 01)

Thank you!